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17 THERMOCHEMISTRY

SECTION 17.1 THE FLOW OF ENERGY—HEAT AND WORK (pages 505–510)

This section explains the relationship between energy and heat, and distinguishes between heat capacity and specific heat.

▶ Energy Transformations (page 505)

1. What area of study in chemistry is concerned with the heat transfers that occur during chemical reactions? _____

2. Where the use of energy is concerned (in a scientific sense), when is work done?

_____

3. Circle the letter next to each sentence that is true about energy.

a. Energy is the capacity for doing work or supplying heat.

b. Energy is detected only because of its effects.

c. Heat is energy that transfers from one object to another because they are at the same temperature.

d. Gasoline contains a significant amount of chemical potential energy.

4. Circle the letter next to each sentence that is true about heat.

a. One effect of adding heat to a substance is an increase in the temperature of that substance.

b. Heat always flows from a cooler object to a warmer object.

c. If two objects remain in contact, heat will flow from the warmer object to the cooler object until the temperature of both objects is the same.

▶ Exothermic and Endothermic Processes (pages 506–507)

5. What can be considered the "system" and what are the "surroundings" when studying a mixture of chemicals undergoing a reaction? Write your answers where indicated below.

System: _____

_____

Surroundings: _____

_____

CHAPTER 17, Thermochemistry *(continued)*

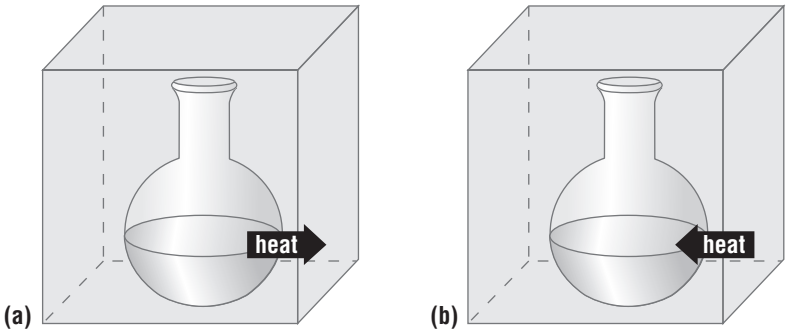
6. In thermochemical calculations, is the direction of heat flow given from the point of view of the system, or of the surroundings?

_____

7. What universal law states that energy can neither be created nor destroyed and can always be accounted for as work, stored potential energy, or heat?

_____

Questions 8 through 12 refer to the systems and surroundings illustrated in diagrams (a) and (b) below.



8. Which diagram illustrates an endothermic process? _____

9. Is heat flow positive or negative in diagram (a)? _____

10. Which diagram illustrates an exothermic process? _____

11. Is heat flow positive or negative in diagram (b)? _____

12. What does a negative value for heat represent?

_____

To answer Questions 13 and 14, look at Figure 17.2 on page 506.

13. A system is a person sitting next to a campfire. Is this system endothermic or exothermic? Explain why.

_____

_____

14. A system is a person who is perspiring. Is this system endothermic or exothermic? Explain why.

_____

_____

_____

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▶ Units for Measuring Heat Flow (page 507)

15. Heat generated by the human body is usually measured in units called _____ .

16. Describe the chemical reaction that generates heat in the human body.

_____

17. What is the definition of a calorie?

_____

_____

18. How is the calorie (written with a lower case c) related to the dietary Calorie (written with a capital C)?

_____

19. Circle the letter next to the SI unit of heat and energy.

a. calorie

b. Calorie

c. joule

d. Celsius degree

▶ Heat Capacity and Specific Heat (pages 508–510)

20. Is the next sentence true or false? Samples of two different substances having the same mass always have the same heat capacity. _____

21. Compare the heat capacity of a 2-kg steel frying pan and a 2-g steel pin. If the heat capacities of these objects differ, explain why.

_____

22. Is the next sentence true or false? The specific heat of a substance varies with the mass of the sample. _____

SECTION 17.2 MEASURING AND EXPRESSING ENTHALPY CHANGES (pages 511–517)

This section explains how to construct equations and perform calculations that show enthalpy changes for chemical and physical processes.

▶ Calorimetry (pages 511–513)

1. The property that is useful for keeping track of heat transfers in chemical and physical processes at constant pressure is called _____ .

2. What is calorimetry? _____

_____

3. Use Figure 17.5 on page 511. Circle the letter next to each sentence that is true about calorimeters.

a. The calorimeter container is insulated to minimize loss of heat to or absorption of heat from the surroundings.

b. Because foam cups are excellent heat insulators, they may be used as simple calorimeters.

c. A stirrer is used to keep temperatures uneven in a calorimeter.

d. In the calorimeter shown in Figure 17.5, the chemical substances dissolved in water constitute the system and the water is part of the surroundings.

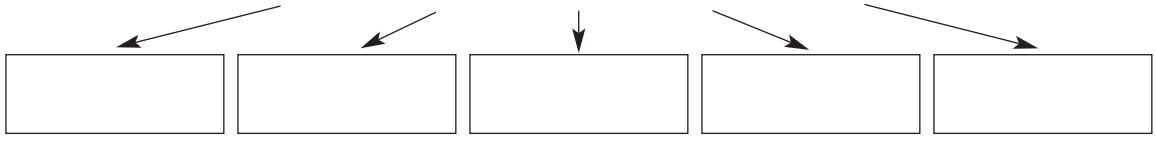
4. Is the following sentence true or false? For systems at constant pressure, heat flow and enthalpy change are the same thing. _____

5. Complete the table below to show the direction of heat flow and type of reaction for positive and negative change of enthalpy.

Sign of Enthalpy Change	Direction of Heat Flow	Is Reaction Endothermic or Exothermic?
ΔH is positive ($\Delta H > 0$)		
ΔH is negative ($\Delta H < 0$)		

6. Name each quantity that is represented in the equation for heat change in an aqueous solution.

$$q = \Delta H = m \times C \times \Delta T$$



▶ Thermochemical Equations (pages 514–517)

7. What happens to the temperature of water after calcium oxide is added?

_____

8. A chemical equation that includes the heat change is called a _____ equation.

9. Why is it important to give the physical state of the reactants and products in a thermochemical equation?

_____

_____

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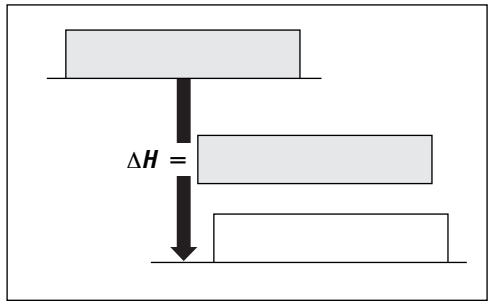
10. Complete the enthalpy diagram for the combustion of natural gas. Use the thermochemical equation in the first paragraph on page 517 as a guide.



SECTION 17.3 HEAT IN CHANGES OF STATE (pages 520–526)

This section explains heat transfers that occur during melting, freezing, boiling, and condensing.

▶ Heats of Fusion and Solidification (pages 520–521)

1. Is the following sentence true or false? A piece of ice placed in a bowl in a warm room will remain at a temperature of 0°C until all of the ice has melted.

_____

2. Circle the letter next to each sentence that is true about heat of fusion and heat of solidification of a given substance.

a. The molar heat of fusion is the negative of the molar heat of solidification.

b. Heat is released during melting and absorbed during freezing.

c. Heat is absorbed during melting and released during freezing.

d. The quantity of heat absorbed during melting is exactly the same as the quantity of heat released when the liquid solidifies.

3. Use Table 17.3 on page 522. Determine ΔH for each of these physical changes.

a. $H_2(s) \longrightarrow H_2(l)$ $\Delta H =$ _____

b. $Ne(s) \longrightarrow Ne(l)$ $\Delta H =$ _____

c. $O_2(s) \longrightarrow O_2(l)$ $\Delta H =$ _____

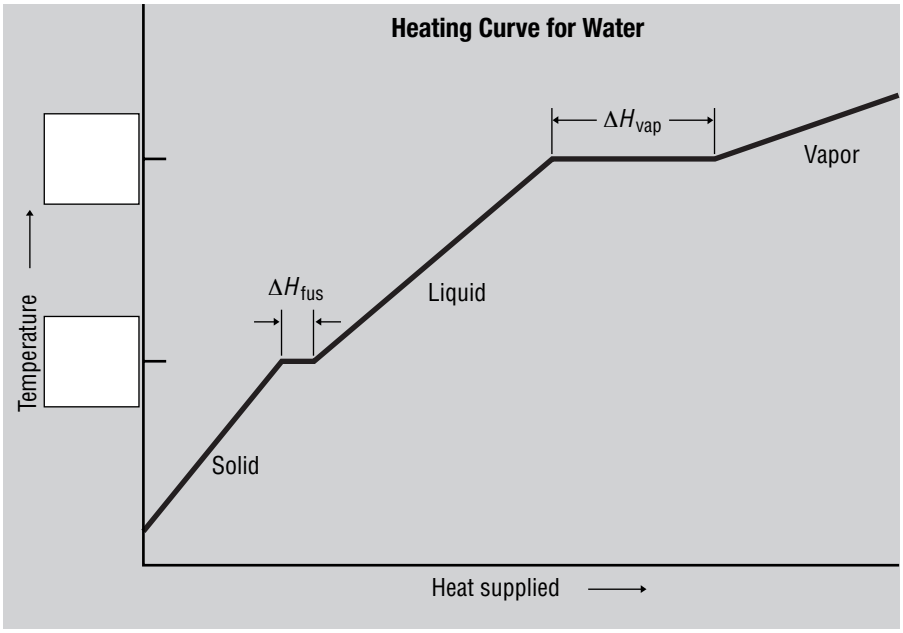
▶ Heats of Vaporization and Condensation (pages 522–524)

4. Is the following sentence true or false? As liquids absorb heat at their boiling points, the temperature remains constant while they vaporize.

_____

CHAPTER 17, Thermochemistry *(continued)*

Use the heating curve for water shown below to answer Questions 5, 6, and 7.



5. Label the melting point and boiling point temperatures on the graph.

6. What happens to the temperature during melting and vaporization?

_____

_____

7. Circle the letter next to the process that *releases* the most heat.

a. Melting of 1 mol of water at 0°C

b. Freezing of 1 mol of water at 0°C

c. Vaporization of 1 mol of water at 100°C

d. Condensation of 1 mol of water at 100°C

Look at Table 17.3 on page 522 to help you answer Questions 8 and 9.

8. How many of the 6 substances listed have a higher molar heat of vaporization than water? Which one(s)? _____

9. It takes _____ of energy to convert 1 mol of methanol molecules in the solid state to 1 mol of methanol molecules in the liquid state at the normal melting point.

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▶ Heat of Solution (pages 525–526)

10. The heat change caused by dissolution of one mole of a substance is the _____ .

11. How does a cold pack containing water and ammonium nitrate work?

_____

_____

_____

Reading Skill Practice

Writing a summary can help you remember the information you have read. When you write a summary, write only the most important points. Write a summary for each of the five types of heat changes described on pages 520–526. Your summary should be much shorter than these six pages of text. Do your work on another sheet of paper.

SECTION 17.4 CALCULATING HEATS OF REACTION (pages 527–532)

This section explains how Hess's law of heat summation and standard heats of formation may be applied to find enthalpy changes for a series of chemical and physical processes.

▶ Hess's Law (pages 527–529)

1. For reactions that occur in a series of steps, Hess's law of heat summation says that if you add the thermochemical equations for each step to give a final equation for the reaction, you may also _____ _____ .

2. Is the following sentence true or false? Graphite is a more stable form of elemental carbon than diamond at 25°C, so diamond will slowly change to graphite over an extremely long period of time. _____

3. Look at Figures 17.13 and 17.14 on pages 528 and 529. According to Hess's law, the enthalpy change from diamond to carbon dioxide can be expressed as the sum of what three enthalpy changes?

a. _____

b. _____

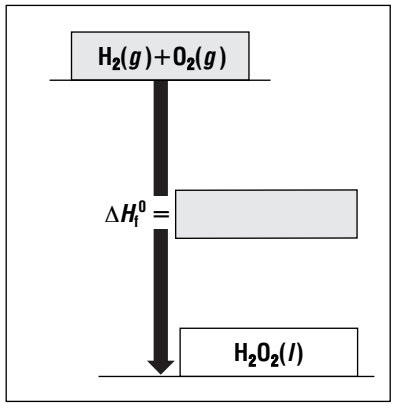
c. _____

▶ Standard Heats of Formation (pages 530–532)

4. The change in enthalpy that accompanies the formation of one mole of a compound from its elements with all substances in their standard states at 25°C and 101.3 kPa is called the _____ .

5. Is the following sentence true or false? Chemists have set the standard heat of formation of free elements, including elements that occur in nature as diatomic molecules, at zero. _____

6. Complete the enthalpy diagram below by finding the heat of formation when hydrogen and oxygen gases combine to form hydrogen peroxide at 25°C. Use the data in Table 17.4 on page 530 and the equation $\Delta H^0 = \Delta H_f^0$ (products) − ΔH_f^0 (reactants) to find the answer.



7. Look at Table 17.4. Methane burns to form carbon dioxide and water vapor.

$$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(g)$$

a. Will the heat of this reaction be positive or negative? How do you know?

_____

_____

_____

b. How does your experience confirm that your answer to Question 7a is reasonable?

_____

_____

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GUIDED PRACTICE PROBLEMS

GUIDED PRACTICE PROBLEM 3 (page 510)

3. When 435 J of heat is added to 3.4 g of olive oil at 21°C, the temperature increases to 85°C. What is the specific heat of the olive oil?

Analyze

a. What is the formula for calculating specific heat? _____

b. What are the knowns and the unknown in this problem?

Knowns:

m = _____

q = _____

ΔT = _____

Unknown:

_____

Calculate

c. Substitute the known values into the equation for specific heat and solve.

$C_{\text{olive oil}}$ = [ ] = 2.0 [ ]

Evaluate

d. Explain why you think your answer is reasonable. Think about the time it takes to fry foods in olive oil versus the time it takes to cook foods in boiling water.

_____

_____

_____

_____

_____

e. Are the units in your answer correct? How do you know?

_____

_____

GUIDED PRACTICE PROBLEM 12 (page 513)

12. When 50.0 mL of water containing 0.50 mol HCl at 22.5°C is mixed with 50.0 mL of water containing 0.50 mol NaOH at 22.5°C in a calorimeter, the temperature of the solution increased to 26.0°C. How much heat (in kJ) was released by this reaction?

a. Calculate the final volume of the water. V_{final} = 50.0 mL + 50.0 mL = _____

b. Calculate the total mass of the water, using the density of water. m = _____ mL × $\frac{\square\ \text{g}}{\text{mL}}$ = _____

c. Calculate ΔT. ΔT = 26.0 °C − _____ °C = _____ °C

d. Substitute the known quantities into the equation for changes in enthalpy (ΔH). ΔH = (_____ g) × (4.18 _____) × _____ °C

e. Solve. _____ J

f. Convert joules to kilojoules (kJ) and round to three significant figures. _____ J × $\frac{1\ \text{kJ}}{1000\ \text{J}}$ = _____ kJ

EXTRA PRACTICE (similar to Practice Problem 14, page 516)

14. When carbon disulfide is formed from its elements, heat is absorbed. Calculate the amount of heat (in kJ) absorbed when 8.53 g of carbon disulfide is formed.

$C(s) + 2S(s) \longrightarrow CS_2(l)$ ΔH = 89.3 kJ

GUIDED PRACTICE PROBLEM 22 (page 521)

22. How many grams of ice at 0°C could be melted by the addition of 0.400 kJ of heat?

a. Write the conversion factors from ΔH_{fus} and the molar mass of ice. $\frac{1\ \text{mol ice}}{\square\ \text{kJ}}$ and $\frac{\square\ \text{g ice}}{1\ \text{mol ice}}$

b. Multiply the known heat change by the conversion factors. $0.400\ \cancel{\text{kJ}} \times \frac{1\ \cancel{\text{mol ice}}}{\square\ \cancel{\text{kJ}}} \times \frac{\square\ \text{g ice}}{1\ \cancel{\text{mol ice}}}$ = ☐ g ice

EXTRA PRACTICE (similar to Practice Problem 23, page 524)

23. How much heat (in kJ) is absorbed when 88.45 g $H_2O(l)$ at 100°C and 101.3 kPa is converted to steam at 100°C? Express your answer in kJ.